In : Lee, Jeffrey A. and Zobeck, Ted M., 2002, Proceedings of ICAR5/GCTE-SEN Joint Conference, International Center for Arid and Semiarid Lands Studies, Texas Tech University, Lubbock, Texas, USA Publication 02-2 p. 377

Aeolian influences on the soils and landforms in semi-arid south-western Australia

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Introduction

Aeolian influences on the soils and geomorphology of semi-arid south-western Australia have been previously reported in several studies. Within a landscape developed on deeply weathered, granitic rocks there are several overt aeolian features, these including clayey and sandy saltation deposits ("lunettes") adjacent to playas (Stephens and Crocker 1946), gypseous and clayey deposits ("lake parna") downwind of playas (Bettenay 1962), the wind-induced shaping of playas (Killigrew and Gilkes 1974) and source bordering sand dune systems adjacent to ephemeral stream lines (Beard 1982). Severe, recurrent wind erosion is a contemporary hazard for sustainable land use (Harper et al. 2002). Developing an understanding the processes that have distributed materials across landscapes is important as it provides a conceptual framework for more efficient soil survey and mineral exploration. This in turn may provide a basis for better land management. Similarly, aeolian features provide a means of interpreting the past responses of these landscape to climate change and changes in hydrology induced by agricultural development. In this paper we describe the aeolian features that occur in a study area on the Yilgarn Craton, near Cairlocup, Western Australia, with soils and landscapes typical of much of the region.

Regional setting: the south-western Australian physical environment

South-western Australia is dominated by the Yilgarn Craton, one of the former nuclei of Gondwanaland. This extends 900 km in a north-south direction, and has an east-west width of 700 km. It is comprised mainly of granites and gneisses with the widespread intrusion of dolerite dykes (Johnstone et al. 1973).

The drainage pattern of the Yilgarn Craton comprises inland areas with broad, flat floored valleys with sluggish drainage, whereas well defined drainage lines occur on the western and southern periphery. Progressive changes in valley form occur along specific drainage lines. Going from inland towards the coast these include greater relative relief, a change from flat to incised valley floors and steeper drainage gradients. Whereas the inland drainage lines can be up to 15 km wide and be in landscapes with up to 60 m relief, closer to the coast drainage lines are narrow and relief ranges up to 300 m (Mulcahy 1967).

Deep weathering has been extensive across the region, with resultant profiles often extending to depths of 50 m or more. These weathering profiles occur on diverse rocks and are often termed laterites (Gilkes *et al.* 1973), with a distinctive sequence of horizons. These include a sandy surface horizon underlain successively by ferricrete, weathered clays, saprolite and parent rock. The differential stripping of these profiles in relation to drainage lines provides an array of soil parent materials. In the upper catchments of the palaeo-river systems there is little relief, and the limited stripping that does occur is to local rather than regional base levels. Products of weathering, such as sand and solutes,

tend to be retained in these landscapes. It is in such an environment that the present study was based.

Study area and methods

Details of the Cairlocup study area, which is 400 km south-east of Perth the capital of Western Australia, and the methods employed are described in Harper et al. (2002).

Unequivocal aeolian features

Playas: Several playas occur in the valley floor, those containing water being elliptical in shape, as with others in the region. This elliptical shape has been interpreted as being due to the action of wind driven waves and currents (Killigrew and Gilkes 1974). Drilling in the valley floor indicated the occurrence of sediments to at least 30 m depth. Several playas were vegetated at the time of land development but have subsequently become salinized.

Lunettes and lunette arrays: Clayey aeolian saltation deposits occur either as single members or multiple arrays on the south-eastern shore of both contemporary and relict playas. These invariably have crescentic shapes, these forming in response to the elliptical shape of the playa shoreline. In some instances lunettes have shapes indicative of playas larger than those currently present. Similarly, the valley floor is dominated by a seven member, 5 km long, multiple lunette array, the lunettes ranging in height from 1-14 m (Fig. 1). Two and three member lunette arrays have been previously reported from in Texas (Reeves 1965) and South Australia (Campbell 1968).

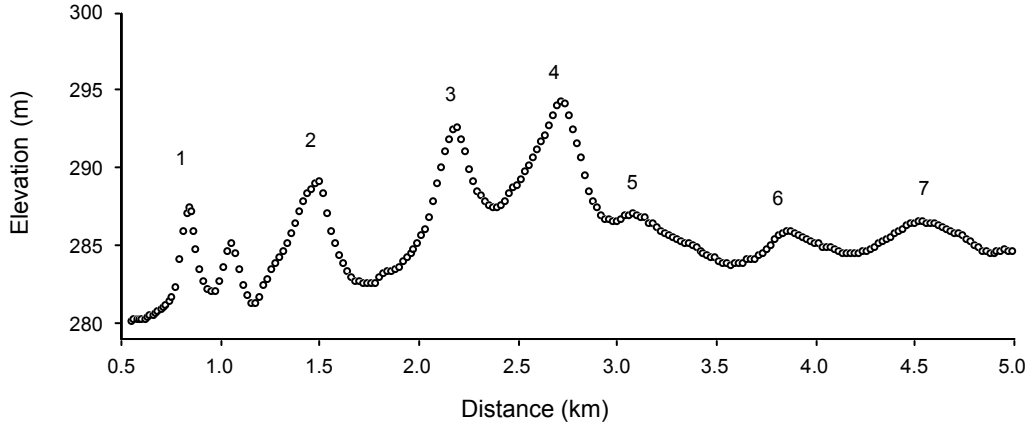

Fig. 1. NW-SW transect surveyed from the major playa, Lake Cairlocup. The distant lunettes are very subtle with amplitudes of 1- 2 m.

There are systematic changes in several soil attributes with distance along the Lake Cairlocup lunette array. Not only are the more distant lunettes relatively subtle in morphology (~2 m high), but there are also systematic differences in soil profile composition and morphology along the lunette array. Whereas profiles close to Lake Cairlocup are alkaline throughout, have loamy surface horizons and contain relatively large amounts (>25%) of diffuse carbonates, distant profiles have sandy surface horizons, contain carbonates both as nodules and soft segregations in discrete horizons, and have acidic upper horizons.

Sand dunes and sheets: Sand dunes and sheets occur both in the valley floor and surrounding hills within a distinct 10 km long and 2 km wide strip, downwind of the ephemeral Cairlocup Creek. These are most likely saltation deposits associated with a former source-bordering sand dune system.

Contemporary wind erosion: Severe and recurrent, contemporary wind erosion represents a hazard to sustainable land use. This is described in more detail in Harper et al. (2002).

Inferred or subtle aeolian features

A more widespread, but subtle, aeolian influence on the soils is likely.
Dust deposits: The occurrence of dust deposits can be inferred from the presence of the clayey lunettes. These are aeolian saltation deposits and their formation would have been accompanied by the evolution of aeolian suspension loads. Although a discrete silty horizon does not occur, field evidence for dust accessions includes the occurrence of calcareous and illitic materials in soils south-east of the major playa, in an apparent plume. Soils outside this plume are mostly acidic and kaolinitic.
Asymmetrical slope deposits: Deep sandy soils occur on many south-easterly slopes and may result from the interaction of topography with sand transport. Such soils occur both in the lateritised granitic terrain, and valley floor lunettes. The occurrence of these may be due to the preferential aeolian deposition of sands on the lee-side of ridges, due to the interference of topography on wind flow and hence sand transport.

Discussion

Lunettes as palaeo-hydrologic indicators

The onset of dryland salinity is a major problem in south-western Australia with 3 Mha of land considered at risk. This salinity has been caused by the replacement of deep rooted xerophytic vegetation with shallow rooted annual plants and the consequent rise of water tables.
Clayey lunettes are playa shoreline deposits and the occurrence of extensive lunette arrays can be used to interpret previous landscape responses to fluctuations in hydrology. Playas have responded to changes in regional hydrology by expanding during pluvial periods and contracting with arid phases. The formation of clayey lunettes requires drying of the playa bed, and sandy lunettes may result from sand transport by currents to the shores of water-filled playas, hence lunette composition may be related to regional hydrological, and hence climatic conditions (Bowler 1983).
The multiple lunette arrays are stranded shore-line deposits, deposited by playas migrating, or receding, to the north-west. They have not been previously described in the broad valley floors of south-western Australia. Many of the lunettes have shapes indicating formation adjacent to playas much larger than presently occur. Together, this indicates a wetter landscape in the past, with more extensive salinization of the valley floors. Many of these areas had a cover of natural vegetation at the time of land development, with this indicating, in a general sense, that salinization is reversible.

Aeolian influences on soil patterns

A strong aeolian influence is evident across the Cairlocup landscape, with features such as elliptical playa shapes, the orientation of the lunettes with respect to source playas and parabolic blowouts in clayey lunettes suggesting that the geomorphologically most effective winds have been from the north-west. Moreover, the lunette arrays are chronosequences, and their consistent orientation suggests uniformity of winds over a long period.

These features are relatively simply recognised. It is clear however, that there have been more extensive aeolian influences on this landscape, these including the extensive lunette arrays with very subtle lunettes, source bordering sand deposits that occur up to 10

km from source, topographically controlled saltation deposits and a thin veneer of aeolian dusts. The occurrence of these features have implications for soil surveys in such environments, particularly where these often rely on topographic models of soil distribution and mineral exploration where bedrock properties are often inferred from analysis of surficial materials.

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